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Feasibility Study on Magnetic Content Addressable Memory

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Principle Investigator: Weizhong Wang

Electrical Engineering and Computer Science Department
College of Engineering and Applied Science,
University of Wisconsin ? Milwaukee
3200 N Cramer St, Milwaukee, WI 53201-0784
Phone: (414) 229-2247, email: wwang@uwm.edu

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Weizhong Wang
Electrical Engineering and Computer Science Department
University of Wisconsin ? Milwaukee
3200 N Cramer St, Milwaukee, WI 53211
Phone: (414)229-2247, E-mail: wwang@uwm.edu
Award Number: N00014-06-1-0942

Objectives

The objective of this project is to investigate the feasibility of the novel magnetic content addressable memory (MCAM) design. The proposed MCAM is to integrate the data storage function and logic XOR function together by using the unique feature in Magnetic Tunneling Junction (MTJ).

Approach

The major challenge in the proposed MCAM cell design is to individually program the two ferromagnets in MTJ. Since the MTJ operation is based on tunneling current, two ferromagnets are separated by 2nm or less. It is very difficult to program one ferromagnet without disturbing the other one 2nm away.

The proposed programming approach is to use layer thickness difference to make one ferromagnet harder, so that the softer one can be programmed by external field without disturbing the harder one. For the harder ferromagnet, the programming field will be enclosed inside a ring shaped structure, so that the softer ferromagnet is not disturbed during the harder ferromagnet programming phase.

We used LLG micromagnetic simulator to answer following questions:

(1) Whether the proposed device operation principle is feasible or not?
(2) Whether the proposed operation principle can work properly with some non-ideal structures introduced during fabrication process?
(3) What are the proper ferromagnetic materials for MCAM?

Work Completed

Since LLG micromagnetic simulator is new to us, we ran a set of LLG simulations based on experimental setting published in PRL Vol. 94, 106601. The simulation results are compared against published results. In addition, we have calibrated the simulator in convergence tolerance setting and the stable state search approaches (energy based or time based).

The feasibility of the MCAM operation in perfect 損icture frame? structure was simulated on both Permalloy and Cobalt based structures. The magnetic field distributions were simulated by using Ansoft Maxwell software package. The simulated magnetic field was then imported into LLG micromagnetic simulator to study the magnetization process. A complete switching cycle consists of following four simulations:

(1) From counterclockwise to clockwise switching under external magnetic field
(2) Relaxation after clockwise switching with external field removed
(3) From clockwise to counterclockwise switching under external magnetic field
(4) Relaxation after counterclockwise switching with external field removed.

Six non-ideal structures are simulated to evaluate the impacts on magnetizations from those non-ideal structures. The six non-ideal structures are listed below:
(1) Changing thickness of the vertical bars
(2) Extra pieces at the ends of horizontal bars
(3) Extra pieces in the middle of the vertical bars
(4) Extra pieces in the two ends of the vertical bars
(5) Extra piece in the left vertical bar
(6) Un-even top horizontal bar

Results

In LLG simulator calibration work, there is good matching between our simulated results and published data. In addition to magnetic field induced magnetization, this simulation also included domain wall moving induced by spin polarized current.

In both Permalloy and Cobalt based 損erfect picture frame? structure tests, all four switching operated as expected. Both top and bottom ferromagnets can be programmed without disturbing the other ferromagnet.

In five out of six simulated non-ideal structures, there are vertices existing in the final states. However, those vertices are all far away from the MTJ junction. Since the read current is orders of magnitude below the threshold current density level to trigger spin torque induced domain wall movement. The MTJ read-out results should not be affected.

With the support of this grant, we have also done some exploratory work on Magnetic Tunneling Junction based bio-sensor study. One presentation and one journal paper are the result of this work.

Journal papers acknowledged this ONR grant support

(1) 揃 agnetic Content Addressable Memory? Weizhong Wang and Zhenye Jiang, accepted to be published on IEEE Transaction on Magnetics June 2007
(2) 揮hermally Assisted Magnetic Tunneling Junction for Bio-sensing Applications? Weizhong Wang and Zhenye Jiang, accepted to be published on IEEE Transactions on Magnetics June 2007

Presentations acknowledged this ONR grant support

(1) 揃 agnetic Content Addressable Memories? W. Wang and Z. Jiang, 10th Joint MMM/Intermag Conference, Baltimore, MD Jan. 7-11, 2007
(2) 揂ltra Sensitive Magnetic Bio-sensors? W. Wang and Z. Jiang, 10th Joint MMM/Intermag Conference, Baltimore, MD Jan. 7-11, 2007

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
College of Engineering and Applied Science, University of Wisconsin - Milwaukee
3200 N Cramer St,
Milwaukee, WI 53201-0784

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14. ABSTRACT

The objective of this project is to investigate the feasibility of the novel magnetic content addressable memory (MCAM) design. The proposed MCAM is to integrate the data storage function and logic function together by using theMagnetic Tunneling Junction (MTJ). The major challenge is to individually program the two ferromagnets in MTJ which are separated by 2 nm. Our approach is to use layer thickness difference and magnetic field confinement within the ferromagnetic materials for programming. We used LLG micro-magnetic simulator to investigate the feasibility of the proposed MCAM operation. The feasibility studies covers both Cobalt and Permalloy based devices. The simulated structures included ideal "picture frame" structure" as well as structures with non-ideal parts which can be introduced during fabrication. In all cases, the simulation results indicate that the MCAM can operate as expected. There are some vortex states introduced in non-ideal structures. However, the read currents are orders of magnitude below threshold current for domain wall movement. The MCAM is expected to work with those non-ideal structures.

15. SUBJECT TERMS
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